(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 289 223 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
05.03.2003 Bulletin 2003/10

(51) Int Cl.7: **H04L 29/06**, H04L 12/56

(21) Application number: 02016991.8

(22) Date of filing: 05.08.2002

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR IE IT LI LU MC NL PT SE SK TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 29.08.2001 US 316849 P
04.02.2002 US 68525

(71) Applicant: ALCATEL
75008 Paris (FR)

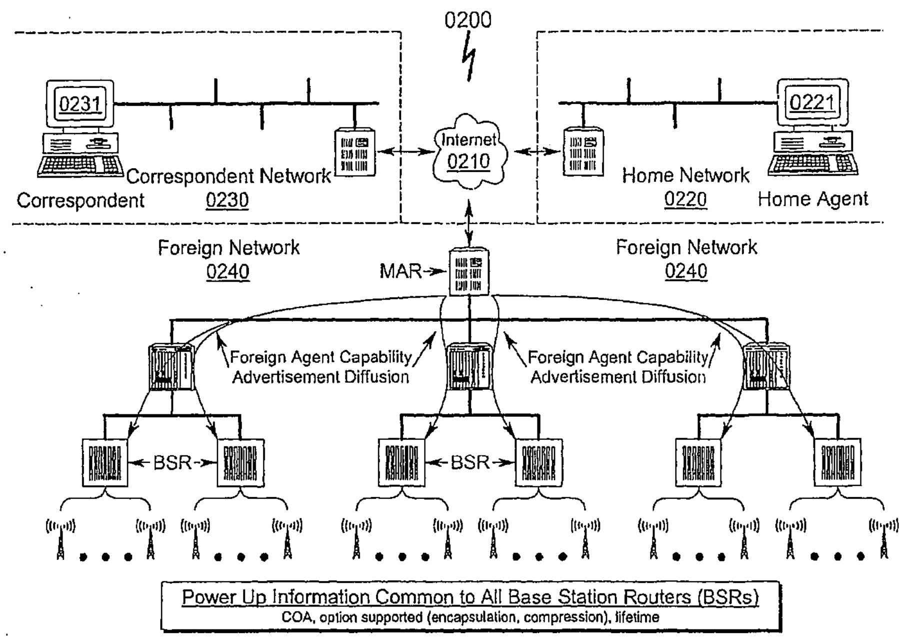
(72) Inventors:
- Magret, Vincent
Oak Park, California 91377 (US)
- Kumar Choyi, Vinod
Plano, Texas 75075 (US)
- Sarikaya, Behcet
Plano, Texas 75024 (US)

(74) Representative:
Dreiss, Fuhlendorf, Steimle & Becker
Patentanwälte
Postfach 10 37 62
70032 Stuttgart (DE)

(54) **Micro-mobility network routing system and method**

(57) A micro-mobility network routing system and method implementing a protocol that extends the macro mobility support of Mobile IP to support micro mobility is disclosed which permits a more efficient and easily implemented Internet routing protocol for network devices to be affected. The macro mobility feature herein refers to the notion in which the mobile node gains access to the Internet, while retaining the same IP address. This concept is used only once when the mobile node enters the coverage area of a foreign domain (eventually its home domain). The concept of micro mobility within this context eases routing packets to the mobile node while its moves within the foreign network. The present invention implements these new features via the use of message compositions and protocol extensions that extend the prior art Mobile IP protocols.

FIG. 2



Printed by Jouve, 75001 PARIS (FR)

Description

CROSS REFERENCE TO RELATED APPLICATIONS

Provisional Patent Applications

[0001] Applicants claim benefit pursuant to 35 U.S.C. § 119 and hereby incorporates by reference Provisional Patent Application for "MICRO-MOBILITY PROTOCOL BASED ON EXPLICIT MULTICAST", S/N 60/316,849, filed 9/29/2001.

PARTIAL WAIVER OF COPYRIGHT

FIELD OF THE INVENTION

Overview

[0004] The Internet has revolutionized the way people day-to-day chores. Whether it is reading our daily morning papers, trading stocks, keeping track of weather, buying clothes or anything else that one can think of. Slowly the technology of wireless communications has improved of the last decade. It started back in the sixties with the first analog radio system to become digital and now in transition to offer broadband access. The reason that this slow revolution of wireless networking is now going to be explosive in the next few years is because now there exists a medium (Internet) to communicate and a tremendous set of applications.

[0005] Mobile IP provides a framework wherein mobile nodes can move from one point of attachment (e.g., a sub-network in an enterprise) to another sub-network (e.g., another sub-network in another enterprise) and will still be able to communicate with nodes. Mobile IP provides the means to keep track of the current location (called a binding in Mobile IP specification) and have all the traffic sent to the mobile node transparently forwarded to the current location. Mobile IP implies that whenever the mobile node moves from one sub-network to another to update the tracking (i.e., the binding) that is maintain in his home network (e.g., the network in which the user is officially registered).

Problem Solution Field

[0006] The problem with Mobile IP is the overhead that is incurred while performing handoff. When the Mobile Host is in a Foreign Network and every time it performs a handoff, Mobile IP Registration Request messages are sent to the Home Agent. The Base Stations in Cellular networks are usually clustered together forming domains along with routers in the upstream that determine where the packets have to be forwarded. One solution to the problem of frequent Registration Request messages being sent to the HA is to take advantage of the domain concept and the topology of the domain (usually Tree-like).

[0007] The present invention is related to the general area of telecommunications and computer network message routing within the context of Mobile IP. While the prior art deals generally with macro mobility within Mobile IP networks, the present invention extends this concept to permit a mobile node to gain access to the Internet while retaining the same IP address. To permit a significant reduction in protocol overhead, the present invention protocol reduces overall network communication to the instance in when the mobile node enters the coverage area of a foreign domain (eventually its home domain).

BACKGROUND AND DESCRIPTION OF THE PRIOR ART

Overview

[0008] Mobile IP offers support to mobile users to roam from one network to another without interruption in its services. The concept suffers from a major drawback when the user's movement imposes high frequency of handoffs on the network. Mobile IP requires the mobile node to inform its home agent of its new location every time it changes its point

of attachment. The concept, which is sometimes referred to as macro-mobility is not suitable when there are frequent handoffs because of the latency that is incurred due to the exchange of registration messages between the mobile node and the Home Agent.

Present Invention Contrasted with Prior Art Solutions

[0009] Micro-mobility is an extension to Mobile IP, and is achieved by hiding the exact location of the mobile node from the home agent so that registration messages do not have to be sent all the way to the HA, instead, the messages are processed locally. The mobile node's exact location is kept local within the wireless domain it has visited. This paper presents a novel protocol designed to address micro-mobility. The protocol is based on IP multicast and has been further refined using Explicit Multicast to address the issues of fast and smooth handoffs. Explicit Multicast has been used to overcome some of the drawbacks of regular IP multicast.

Exemplary Prior Art Solutions

[0010] Several protocols, such as HAWAII [Lucent], Cellular IP [Ericsson], and Hierarchical Foreign Agent, have been proposed to decrease the amount of messages sent to the home agent (HA). Each of these protocols uses the Domain concept to reduce the frequency of messages sent.

[0011] The HAWAII and Cellular IP proposals are very similar, but HAWAII appeals better, because it offers a more complete solution to the above stated problem. An Overview of the design of the protocol is given below. Brief descriptions of the proposals from Singapore University and Hierarchical Micro-mobility management are also given below.

[0012] There are two protocols that have been widely discussed within the IETF and the academic community that are based on host-route based technique. The host-route based techniques uses hop-by-hop mechanism to perform routing whereby, at each hop the entry for the mobile host is searched and the data packets are forwarded using the appropriate interface. The two protocols are HandoffAware Inter-domain infrastructure and Cellular IP. These will now be discussed in detail.

Handoff Aware Inter-Domain Infrastructure [HAWAII]

Overview

[0013] A domain as defined in HAWAII can contain several hundred base stations, thereby increasing the probability that a MN (visiting a foreign domain), after having registered with its home agent, remains within the same wireless domain. In such a scenario the home agent's role is very much reduced.

[0014] HAWAII defines a Domain Root Router (DRR) as the connecting device between the Internet and the wireless domain. The mobile node or mobile host uses the usual Mobile IP concepts when moving for the first time into a foreign domain.

[0015] The protocol requires that the mobile node use a co-located care-of address, an address that is not given by the foreign agent. The address can be obtained for instance via DHCP. The mobile node appends a Network Address Identifier Extension so that the domain can differentiate between a visiting mobile node from a mobile node administrated by the domain. For a visiting node, the base station (i.e., the router that is connected to the base station) creates an entry in the routing cache for the mobile node and forwards the registration request to the home agent of the mobile node. Each node along the path realizes the same operation (i.e., creation of a routing cache's entry) until the message reaches the DRR, from where the registration request is forwarded to the home agent.

[0016] The mobile node must remember the address of the current base station, so that it can provide the IP address along with its registration request when performing a handoff to the new base station. The presence of the Previous Foreign Agent Node Extension helps the base station to determine if the mobile node had previously registered via another base station from within the same wireless domain.

[0017] When the base station detects this extension, it triggers the route update algorithm. Two possibilities are defined depending on the capacity offered by the wireless technology used. If the mobile node can receive packets from two base stations simultaneously, the routing update process goes on until the crossover router (the router that has one interface leading to the old base station and the other one leading towards the new one); this scheme is also called the non-forwarding scheme. In the forwarding scheme wherein the mobile nodes are not capable of simultaneously listening to multiple base stations the route update message is sent till it reaches the old base station. This scheme allows the old base station to forward the packets intended for the mobile node to the mobile node's new location.

[0018] If there is no traffic and the mobile node is not yet idle, the node is required to transmit path update messages. These messages are propagated towards the DRR and at each router in its path the routing entries are refreshed.

[0019] Correspondent nodes send packets to the home address of the mobile node. The home agent intercepts these packets and creates a tunnel using the co-located care-of address of the mobile node. When the packets arrive at the DRR, they are forwarded in a hop-by-hop manner. At this point each hop uses the routing entries previously updated by the MN. This protocol is further extended with a support for paging.

[0020] The general characteristics of HAWAII are as follows:

- Defines a two-level hierarchy along domain boundaries and defines separate mechanisms for inter-domain and intra-domain mobility. A unique co-located care-of-address is assigned to the mobile Host to provide for straightforward QoS support
- Special Paths are established to maintain end-to-end connectivity as the mobile host moves. These paths are used to provide for hop-by-hop routing of packets.
- Soft-state mechanisms are used to provide a degree of tolerance to router or link failures within the network.
- Depending upon the capability of the Mobile Host two different schemes for smooth handoffs are provided. A Non Forwarding Scheme for Mobile Nodes that can receive data simultaneously from two different Base Stations and a Forwarding Scheme for Nodes that can receive data only from one Base Station at a time.

Terminology used in HAWAII

Home Domain

[0021] This is the domain to which a Mobile Node belongs.

Foreign Domain

[0022] Any domain that the Mobile Node visits and is not its Home Domain

Domain Root Router

[0023] Domain Root Router is the Gateway to a Domain

Update Messages

[0024] These are messages sent by the Base Station to the routers upstream to update the entries of a Mobile Node when a handoff occurs or periodically (using a lifetime)

Principles

[0025] The gateway into each domain is called the Domain Root Router. Each host has an IP address and a Home Domain. A domain may cover an area containing a few hundred base-stations, thereby increasing the probability that the mobile host is within its home domain. The home agent's job is very much reduced.

[0026] When a mobile node (MN) moves into a foreign domain, the usual mobile IP concepts come into play. Each mobile host is assigned a unique care-of-address and the address is unchanged when moving within the foreign domain. The home agent tunnels the packets to the care-of-address. The home agent is not notified of movements within the foreign domain and connectivity is maintained using dynamically established paths in the foreign domain.

Sequence of Operations - Power Up

[0027]

- The base station determines if the MN is at home or in a foreign domain by comparing the network access identifier (NAI) sent along with the registration request with the NAI of the current wireless domain.
  If the mobile is at home the base station must create a route entry in every node till the domain root router. Otherwise the base station must forward the registration request to the home agent and create a route entry in every node till the domain root router.

- Packets from a Correspondent Node (CN) are sent to the Home Network of the MN.
- The packets are intercepted by the HA and then tunneled to the MN using the co-located care-of address (CCOA). _When the packets reach the wireless domain they are routed using the hop-by-hop route entries previously created.

Operation Sequence - Intra-domain Movement (Non-Forwarding)

[0028]

- On Receiving a Registration Request from a MN, the Base Station (BS) figures out the old base station as the MN must sent the previous foreign agent extension along with the registration request.
- If the movement was an Intra-domain movement then the BS would send an Hawaii Update message to all the way to the Old BS, updating the cache of all the routers in the path between the new BS and the Old BS
- The Old BS then sends an acknowledgement back to the New BS

[0029] The above operations are done to provide for smooth-handoff

Sequence of Operations - Intra-Domain Handoff

[0030]

- Packets sent by the CN are sent to the MN's home network, the Home Agent intercepts these packets and tunnels them to the CCOA. The DRR then sends the packets downstream through the appropriate interface on a hop-by-hop basis.
- The crossover router then forwards the packets to the next hop router through the interface as per the HAWAII entry.

Cellular IP [CIP]

Overview

[0031] Cellular IP is intended to allow routing of IP datagrams to a mobile host. The protocol along with mobile IP is intended to provide wide-area mobility support. Cellular IP has been designed to be used on a local level, like in a campus or metropolitan area network.

[0032] Cellular IP is similar to HAWAII as it relies on a hop-by-hop principle to handle the traffic within the wireless domain. The protocols differ in the terminology used, the messages and its interaction with Mobile IP. The CIP gateway controls the traffic that is directed to and originating from the CIP domain. The CIP gateway includes two sub-components: the gateway controller and the gateway filter.

[0033] The Gateway Controller (GC) receives packets that are usually update packets that are used by the Gateway to update the locations of the MN and are then dropped. The Filter (GPF) checks to see if packets coming from within the domain are to be sent to the GC or forwarded on to the Internet. One of the primary features of this protocol is the distinction made between idle and active nodes and the support for paging.

Terminology

Cellular IP Node

[0034] A cellular IP network consists of interconnected Cellular IP (CIP) nodes. The nodes route packets inside the Cellular IP network and communicate via wireless interface with mobile hosts.

Gateway Controller

[0035] The Gateway Controller (GC) receives packets that are usually update packets that are used by the Gateway to update the locations of the MN and are then dropped.

Gateway Packet Filter

[0036] The Filter (GPF) checks to see if packets coming from within the domain are to be sent to the GC or forwarded on to the Internet.

Cellular IP Gateway

[0037] It consists of a GC, CIP Node and GPF.

Control Packet

[0038] A route-update and paging-update packet

Paging Cache

[0039] A cache maintained by some Cellular IP nodes used to route packets to mobile hosts

HAWAII and CIP Deficiencies

[0040] The solutions described in previous sections allow for support of micro-mobility. HAWAII requires that the mobile node receive an agent advertisement as defined in Mobile IP before being able to update the routing entries along the path from the DRR to the last router. The latency involved in updating intermediate routers from the BS to the DRR after a handoff may not be in line with requirements for realtime applications. CIP imposes modifications to Mobile IP at the mobile node and the implementation of CIP at every mobile node, which are stringent restrictions and a drawback of the solution. Both protocols may face scalability problems if they are deployed over cellular infrastructure, where the number of users could be very large.

Location Management and Routing

[0041] CIP uses two parallel cache systems to store information related to location of mobile hosts. Mappings for active hosts are maintained in the routing-cache that has a small timeout value when compared to the timeout in paging cache. For a host that performs handoff frequently, the mappings are maintained at the routing-cache. Since the time-out values of the routing-cache are very small, it results in flushing the entry for a mobile from the routing cache of a node. Thus, packets would not be sent to the mobile host's old address resulting in less wastage of resources. An idle host sends fewer update packets since the time-out values for the routing-cache are larger.

Cellular IP Functions

Location Management

[0042] Paging update packets are sent by idle hosts to update the Paging-cache mappings, to reflect the current location but do not modify the routing-cache mappings. Paging update packets are discarded once it reaches the Gateway to prevent Cellular IP specific control operations from reaching the Internet.

[0043] When an IP packet arrives at a Cellular node, addressed to a mobile host for which no up-to-date routing cache mapping is available then the mapping in the paging cache is used to route the packet. This phase is called "Implicit Paging"

Routing

[0044] Packets transmitted by mobile hosts are routed to the gateway using regular hop-by-hop routing, the cellular IP nodes monitor these packets and update their routing-cache entries with the host address and the interface on which they arrived. Packets addressed to the mobile host are routed hop-by-hop in the reverse by the routing cache mappings. Mobile hosts that are active but do not have any data to send must send periodic route-update packets in order to ensure that route-caches are not purged. For reliability paging caches may also contain mobile hosts that are also contained by routing caches.

Handoff

[0045] The mobile host initiates handoff. When a mobile host migrates packets are directed to the new base station and these packets update the caches along its path to the gateway. If there are nodes that share both the paths then the old mappings are refreshed. Packets would be sent to the old base stations and to the new base station for a time equal to the timeout of the route-cache mappings. After the expiration of the timeout the cache entries for the old base stations are cleared.

Wide-Area Mobility

[0046] Wide area mobility occurs when a mobile host moves from one Cellular IP network to another. The mobile nodes distinguish between Cellular IP network by using the Cellular IP network identifier contained in the Base station's beacon signals. The beacon signal also contains the IP address of the gateway. A mobile host can start sending paging-update packets immediately. Upon receiving the first paging-update packet, the gateway performs admission control that could involve charging decisions, etc. Once the request has been accepted the mobile host can send a mobile IP registration message to its home agent specifying the gateway's IP address as care-of-address.

Singapore University Proposal

[0047] This scheme suggests using a hierarchical mobility management architecture to restrict handoff processing within the domain and uses multicast as a mechanism to deliver packets to multiple base stations to achieve fast handoffs.

Terminology

Domain Foreign Agent (DFA)

[0048] The DFA works like a gateway into the domain. The DFA performs all functionality as mentioned in Mobile IP.

Dynamic Virtual Macro-cells (DVMs)

[0049] The base stations are logically organized into DVMs. The DVMs are formed by clusters of base stations adjacent to each other and may even overlap. Each BS may belong to multiple DVMs but each BS can only be the core of only one DVM.

Principles

[0050] MN registers with the IP address of the DFA, which are broadcast on behalf of the DFA by the BS. The DFA assigns a multicast address unique within it domain for the MN. The MN informs the serving BS to subscribe to this multicast address. The BS in turn tells its neighboring BSs to subscribe to the multicast group.

[0051] Packets destined to a MN within a domain are tunneled to the DFA, the DFA then forwards the packets to the multicast address of the MN. BSs subscribed to the multicast group receive the datagrams, and only that BS that serves the MN forwards the packet the other BSs just buffers them.

[0052] A significant disadvantage of this approach is the management of who the core is each time there is a handoff.

Hierarchical Micro Mobility

Terminology

[0053] In this proposed micro mobility scheme, the mobility management protocol is composed of three components:

Access Mobility Management Protocol

[0054] It specified the registration procedures between the MN and the domain it is attached and is independent of the micro and macro-mobility management protocols used in the core of the network

Micro-mobility Management Protocol

[0055] It handles the local mobility within the domain.

Macro-mobility Management Protocol

[0056] It is the protocol that handles macro-mobility (inter-domain) of the MN; Mobile IP is used to achieve macro-mobility

Principles

[0057] The proposal is based on the deployment of Mobility supports (MS). A MS is a router or set of routers that maintains a binding per Mobile nodes currently visiting the domain and also performs the job of sending Bind Updates on behalf of the MN. Typical functions of a MS include:

- Process Registration Messages sent by the MN
- Send Binding Updates to the CN and the HA of the MN
- Intercept and redirect packets addressed to the MN

Sequence of Operations: Entering a New Domain (Inter-domain movement)

[0058]

- Obtains a CoA (also called Physical CoA (PcoA)) and registers with the Mobility Support, by sending its Home Address, home agent address, PcoA and the address of its previous Mobility Support (MS_p) in the previous domain. The registration is acknowledged by the Mobility Support
- Upon receiving a registration message from the MN, the MS allocates a Virtual CoA (VCoA) for the MN and registers with its HA on behalf of the MN. Then it acknowledges the reception of the registration message sent by the MN and the acknowledgement contains the VCoA.
- After the above-mentioned operations the MS asks the MS_p to redirect all packets addressed to the MN to it. MS_p must acknowledge this request and send the list of CN and the list of sequence numbers of the latest Binding updates sent.
- Creates an entry that contains binding between MN's address, its HA, VcoA and the list of CN's and sequence numbers.
- Sends a binding Update to each CN
- MS then creates a binding between the MN's PcoA and VcoA, which is used by the MS to redirect packets addressed to its current point of attachment.

Sequence of Operations: Intra-domain movement

[0059] When a MN moves within a domain (from the coverage of one BS to another, then the MN registers its new point of attachment with the MS. The MS then updates binding entry for the MN replacing the existing PCoA with the new PCoA. Could also send Binding Updates to the MN's local CN's.

Data Flow

[0060] Datagrams sent by a correspondent node are intercepted by the MN's HA and forwarded to the MN's VCoA. The MS intercepts these packets and tunnels them to the PCoA. The MS sends a (Home Address, Border Router) bind update messages to each of the CNs. The CNs on receiving these messages updates the MN's entry and sends the forthcoming packets to the MN's current PcoA.

Multicasting Based Architecture for Internet Host Mobility

[0061] This proposal uses IP multicasting as a mechanism to achieve mobility. Every mobile node is issued a multicast address instead of a unicast address. There is no concept of Home Agent/ Foreign Agent The multicast address is used along with Location Servers and Multicast Routers to achieve mobility. It is not a solution to the problem of micro-mobility. It is protocol that challenges Mobile IP.

Terminology

Location Server (Distributed Directory)

[0062] These are servers that store binding between the multicast address of a MN and the Multicast Router serving the MN. Each MN is responsible for periodically updating its Location Server periodically with information on the Multicast Router (MR) serving it.

Base Station

[0063] In addition to the normal capabilities of base station, in this scheme each base station also has the capability of working as a MR.

Principles

[0064] When a CN sends datagrams intended to a MN (having a multicast address), the multicast router (MR_CN) within the network picks up the datagrams and checks a Location Server for information regarding the MN. The Location Server chosen depends upon the multicast address of the MN.
[0065] On obtaining the address of the Multicast Router (MR_MN) that serves the MN, the MR_CN contacts the MR_MN and joins the multicast group and forwards the datagrams.
[0066] Each MR that receives the datagrams, de-tunnels the datagrams, and forwards them to the MN.
[0067] Before the MN moves from the coverage of one Multicast Router to another, the MN requests the MR within the new network to join the multicast group. Therefore the MN receives packets uninterrupted.
[0068] Therefore the previous MR and the new MR of the MN receives the packets, but the previous MR would stop receiving datagrams after a certain time period.

DEFICIENCIES IN THE PRIOR ART

[0069] While the following list should not be viewed as limiting the scope of the present invention in any way, it does provide some insight into deficiencies of the prior art that in some exemplary embodiments may be corrected by the present invention:

- Cellular IP implies that the mobile node implements that protocol. This is major drawback since it requires an update of every node to be able to take advantage of the say protocol. Beside this important point, the protocol does not detailed how the mobile node should know whether it should use a traditional scheme (i.e. mobile IP) or the cellular scheme.

- Cellular IP and HAWAII both use a hop-by-hop routing protocol, which requires management of huge routing tables when deployed in a big network (e.g. cellular network, in which users are counted in millions). This specific issue implies also that all nodes in the wireless domain must integrated a specific software, thus off the shelf components cannot be used.

- HAWAII does not support the foreign address care-of address scheme offered in mobile IP. In turn, HAWAII requires usage of co-located care-of address. This principle requires the operator to manage a huge number of IP addresses, since it must allocate one IP address per user. Considering the issue that IPv4 already has a lack of address, then the proposal also implies that the network either run some private address scheme or use IPv6.

- The proposal made in Singapore implies that the mobile node sends the multicast address along with the registration request to the new base station. This modifies the protocol on every single mobile node.

- The unified hierarchical model implies that the mobility support registers on the mobile node behalf with the home

agent. The scheme creates a serious security issue. It also modifies mobile IP specification by changing the registration PDU. And finally the mobile node needs to have the IP address of the base station with which it was previously connected.

- The solutions aforementioned do not support a scheme such as "make before break", which is essential for voice over IP applications.
- The last proposal has several drawbacks. There is a limitation in the number of unique class D addresses that can be assigned to each and every MN in IPv4.It requires that every router in a sub-network is mobility-aware. Before a MN moves under a new coverage, it can inform the MR within that area of a possible handoff and request the MR to join the multicast group. Therefore, the MN has to know the address of the neighboring MR, and also the overhead that is involved at the MN every time it performs a handoff. The scalability of using a location server is something that is not very clear.

[0070] One skilled in the art may be able to expand this list, but it does serve to indicate that the prior art has pending technical issues that have yet to be addressed by any Mobile IP protocol.

OBJECTIVES OF THE INVENTION

[0071] Accordingly, the objectives of the present invention are (among others) to circumvent the deficiencies in the prior art and affect the following:

(1) To increase mobility of mobile nodes while maintaining an IP connection.

(2) To reduce the routing overhead associated with current IP routing protocols.

(3) To generally overcome the deficiencies of existing macro-mobility protocols.

[0072] While these objectives should not be understood to limit the teachings of the present invention, in general these objectives are achieved in part or in whole by the disclosed invention that is discussed in the following sections. One skilled in the art will no doubt be able to select aspects of the present invention as disclosed to affect any combination of the objectives described above.

BRIEF SUMMARY OF THE INVENTION

Multicast Micro-Mobility (MMM) Protocol

[0073] The MMM protocol takes advantage of IP multicast to achieve fast handoffs. The base stations as defined by the protocol are not merely passive bridges, but has an active participation in the working of the protocol. Efficient handoffs can be achieved if triggers from the link layer were used to perform network layer handoffs. All routers within the wireless domain are required to support IP multicast routing.

[0074] The Main Access Router (MAR) acts as the Gateway to the wireless domain and supports Mobile IP. The MAR may serve as a foreign agent and/or a home agent. MAR processes registration requests sent by a MN and also processes the BSR extension that are appended to the registration messages. The MAR is also required to allocate and insert a multicast address extension (MAE) before forwarding the registration reply. The MAR makes use of two caches to manage nodes within its domain. The Binding cache has entries for mobile nodes that are presently being served by the MAR. The probable cache has entries for MNs that are expecting to be approved for service by the MAR. Once the MN has been approved for service after having performed the necessary checks and after receiving a registration reply from the MN's HA, the MN entry is moved from the probable cache to the binding cache. The MAR implements the extensions as described in the Mobile IP literature.

[0075] The BSR appends the BSR extension to each Mobile IP registration request and forwards the messages to the MAR. The BSR processes the multicast address extension appended to the Mobile IP registration reply. The BSRs also sends periodic neighbor binding update (NBU) message to every BSR that are on its neighbor list. The BSR manages two caches; the binding cache is used by the BSR to manage mobile nodes under its coverage and the probable cache is used by the BSR to perform fast handoffs for mobile nodes that are under the coverage of its neighboring BSRs. The binding caches are updated by MNAE messages and the probable caches are updated by the NBU message. The NBU message is used by the neighboring BSRs (the definition of "neighboring BSR" is determined by the network operator either statically or dynamically) to manage their probable caches. The Base station Routers (BSR)